Higgs working group summary

Heather Logan
Carleton University

for Sally Dawson, Andrei Gritsan, Jianming Qian,
Chris Tully, and Rick Van Kooten

Snowmass Energy Frontier Workshop
Brookhaven National Laboratory, April 3-6, 2013

Outline

Highlights from this meeting

Focus points of our study

Major controversies still to be resolved

Projects to be finished by June 30

Highlights from this meeting

Useful joint discussions with other working groups

- Common benchmarks with New Physics group

We will evaluate sensitivity to Higgs coupling deviations, NP will evaluate direct-search reach. Need to nail down benchmarks!

- Session on tth issues with Top group

- Discussion of common dimension-6 operators approach with Electroweak group

Evaluate effect of operators on Higgs couplings, compare to sensitivity from vector-boson production

Higgs coupling modifications vs. EW precision fits?

- Session on Higgs cross-sections for hadron colliders with QCD group

Highlights from this meeting

Productive sessions and interesting talks

- Extended Higgs sectors

Good benchmarks for joint studies with NP group

- Higgs coupling theory

Productive discussion of how well we need to measure Higgs couplings

- Higgs coupling measurements

Extremely useful overviews from many (all?) of the Energy Frontier Facilities

- Higgs spin, CP mixtures, and other properties

Broad overview of expt prospects at different facilities

(A lot to be done/updated here)

Snowmass studies in progress for energy frontier facilities

- ILC + luminosity upgrade

- muon collider

- gamma-gamma collider

- CLIC

- LHC experiments? 300 and 3000 fb^{-1}

- TLEP

- VLHC

Focus points of our study

1) Summarize precisions of Higgs coupling measurements across the Energy Frontier facilities and compare their sensitivities to Higgs-coupling deviations in simplified benchmark models

Working Group Output

- General coupling fits+ fits within specific models

	LHC300	LHC3000	ILC250	ILC500	ILC1TeV	CLIC 3 TEV	μμ
Δ_H							
Δ_V							
Δ_f							
Δ_b							
Δ_τ							
Δ_V							
...							

See recommendations of LHC Higgs Cross Section Working Group

We are happy to add columns if people are willing to generate the entries.

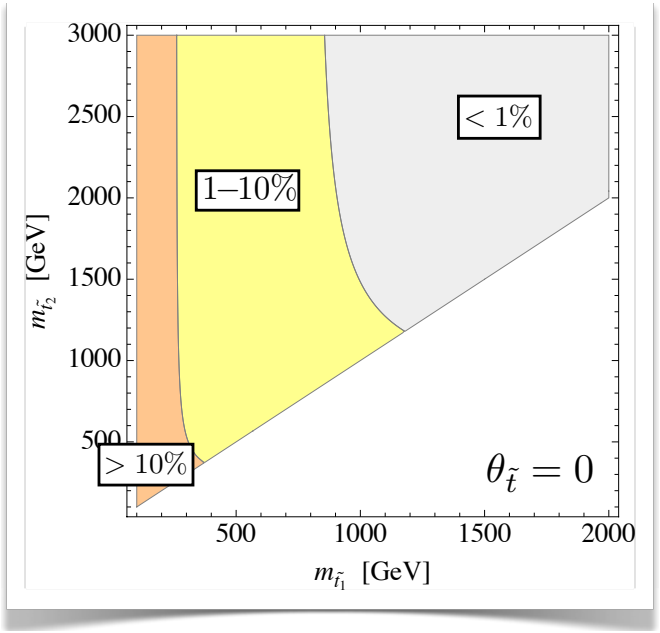
Focus points of our study

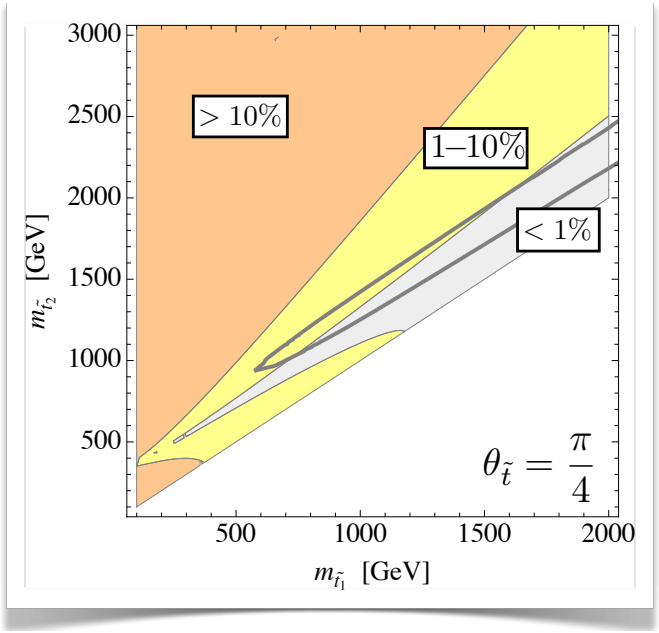
2) Quantify the reach in New Physics sensitivity for a given precision of Higgs-coupling measurement

"How well do we need to measure the Higgs couplings?"

Stop

$$\Delta_g^{\tilde{t}} \simeq \frac{1}{4}\left[m_t^2\left(\frac{1}{m_{\tilde{t}_1}^2}+\frac{1}{m_{\tilde{t}_2}^2}\right)-\frac{1}{4}\left(\frac{m_{\tilde{t}_2}}{m_{\tilde{t}_1}}-\frac{m_{\tilde{t}_1}}{m_{\tilde{t}_2}}\right)^2\sin^2 2\theta_{\tilde{t}}\right]$$





Brian Batell

Focus points of our study

3) Summarize the capabilities of Energy Frontier facilities to measure the CP properties (tensor structure) of the Higgs couplings

- Operator sensitivity in final-state kinematic distributions

  $h \to ZZ$, WW

  What about $t\bar{t}h$ or $h \to \tau\tau$?

- Initial-state control over CP quantum numbers

  Muon and photon colliders

	LHC 300/fb	LHC 3000/fb	e^+e^- 250 GeV	e^+e^- 1 TeV	$\mu^+\mu^-$ 125 GeV	$\gamma\gamma$ 125 GeV
spin-2 Grav.	$\sim 10\sigma$	$\gg 10\sigma$	?	?	?	?
...	...	...	...	...	...	...
f_{CP} in VVH	± 0.08	± 0.03 (?)	?	?	?	?
f_{CP} in $\tau\tau H$	?	?	?	?	?	?
f_{CP} in ttH	?	?	–	?	–	–
f_{CP} in $\mu\mu H$	–	–	–	–	?	–
f_{CP} in $\gamma\gamma H$	–	(?)	–	–	–	?

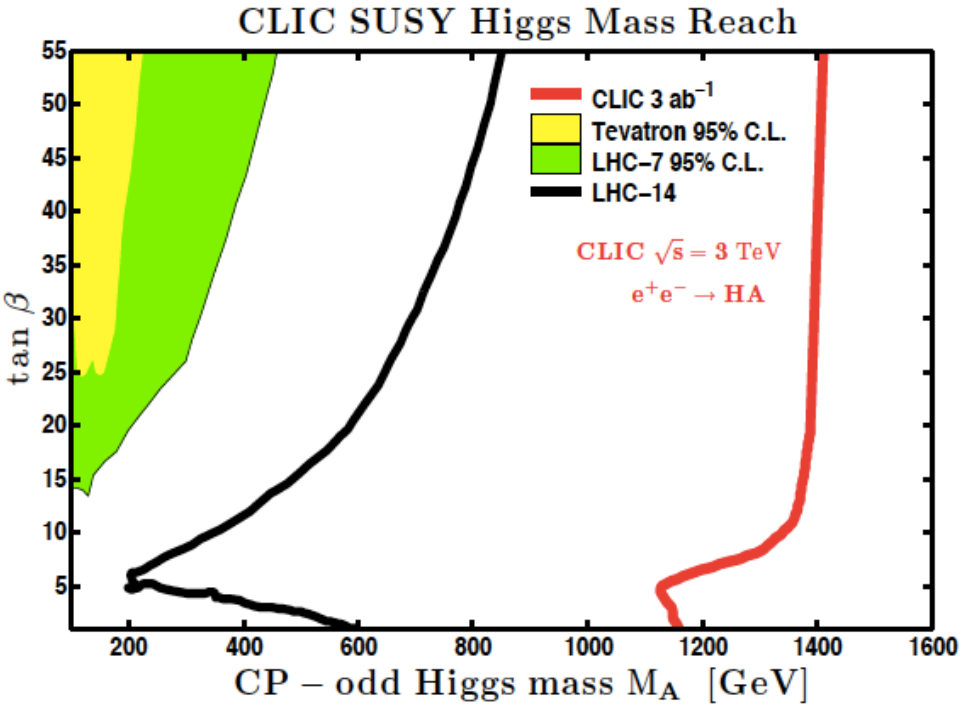
A. Gritsan XI 5 April 2013

Focus points of our study

4) Summarize the capabilities of Energy Frontier facilities to discover the heavy $H, A, H^{\pm}$ of the MSSM (or 2HDMs)

heavy Higgs searches

CLIC access to SUSY heavy Higgs searches



Major controversies/questions still to be resolved

1) Summarize precisions of Higgs coupling measurements across the Energy Frontier facilities and compare their sensitivities to Higgs-coupling deviations in simplified benchmark models

More solid numbers still needed from ATLAS and CMS for both 300 fb^{-1} and 3000 fb^{-1}

Important to avoid misleading comparisons of e^+e^- projects: need a common standard for the run time (years) at a given CM energy $\rightarrow$ translate to number of Higgs produced

We will do the sensitivity fits within specific simple models

Major controversies/questions still to be resolved

2) Quantify the reach in New Physics sensitivity for a given precision of Higgs-coupling measurement

What do we learn from the Higgs self-coupling measurement? (BSM benchmarks? Electroweak baryogenesis?)

We will compare NP benchmarks on an equal footing: 95% CL exclusion and 5σ discovery standards. A 10% coupling deviation requires 2% precision to discover at 5σ.

Major controversies/questions still to be resolved

3) Summarize the capabilities of Energy Frontier facilities to measure the CP properties (tensor structure) of the Higgs couplings

What are the expectations for CP violation in Higgs couplings in interesting models? (link to baryogenesis?)

How do the capabilities of the Energy Frontier measurements of CP violating Higgs couplings compare to current and proposed EDM experiments?

Major controversies/questions still to be resolved

4) Summarize the capabilities of Energy Frontier facilities to discover the heavy $H, A, H^{\pm}$ of the MSSM (or 2HDMs)

Updated numbers from ATLAS and CMS for both 300 fb^{-1} and 3000 fb^{-1}?

Projects to be finished by June 30 $\leftarrow$ **!!!!**

June 21 - Draft of bulleted list of WG conclusions (1 page) to EF conveners

June 30 - Bulleted lists circulated among conveners
June 30 - Your inputs needed for WG report first draft!

July 15 - First draft of 30-page WG report to EF conveners

July 24 - EF conveners distribute first draft of their overall report

August 30 - Final versions of all reports due

September 30 - Cutoff date for Snowmass proceedings

Projects to be finished by June 30

1) Summarize precisions of Higgs coupling measurements across the Energy Frontier facilities and compare their sensitivities to Higgs-coupling deviations in simplified benchmark models

Compute uncertainties on underlying few-parameters from expt inputs

Compute effects on Higgs couplings from dimension-6 electroweak operators

Projects to be finished by June 30

2) Quantify the reach in New Physics sensitivity for a given precision of Higgs-coupling measurement

Decide on NP/Higgs benchmarks!

Compute significance of benchmark Higgs deviations from expt inputs

Solicit benchmarks for NP reach from loop-induced Higgs couplings

Solicit some NMSSM benchmark points from Pittsburgh/Arizona group

Survey double Higgs production studies for NP sensitivity

Projects to be finished by June 30

3) Summarize the capabilities of Energy Frontier facilities to measure the CP properties (tensor structure) of the Higgs couplings

Compute the muon EDM from $h\mu\mu$ CPV and compare to muon EDM expts

Compute effect of CPV in $t\bar{t}h$ coupling upon $h\gamma\gamma$ CPV

Recruit expert theorist(s) to evaluate EDM constraints on $h\gamma\gamma$ CPV

Recruit expert theorist(s) to link Higgs CPV to baryogenesis

Recruit a study of CPV coupling sensitivity in $h \to \tau\tau$ and in $t\bar{t}h$

Projects to be finished by June 30

4) Summarize the capabilities of Energy Frontier facilities to discover the heavy $H, A, H^{\pm}$ of the MSSM (or 2HDMs)

Redo the MSSM reach plot $(M_A, \tan\beta)$ from light Higgs measurements

Projects to be finished by June 30

Overall facilities comparison

Summarize best capabilities from each facility

Summarize what measurements cannot be done at each facility

Projects to be finished by June 30 $\leftarrow$ **!!!!**

June 21 - Draft of bulleted list of WG conclusions (1 page) to EF conveners

June 30 - Bulleted lists circulated among conveners `Seattle WS`
June 30 - Your inputs needed for WG report first draft!

July 15 - First draft of 30-page WG report to EF conveners

July 24 - EF conveners distribute first draft of their overall report

August 30 - Final versions of all reports due

September 30 - Cutoff date for Snowmass proceedings

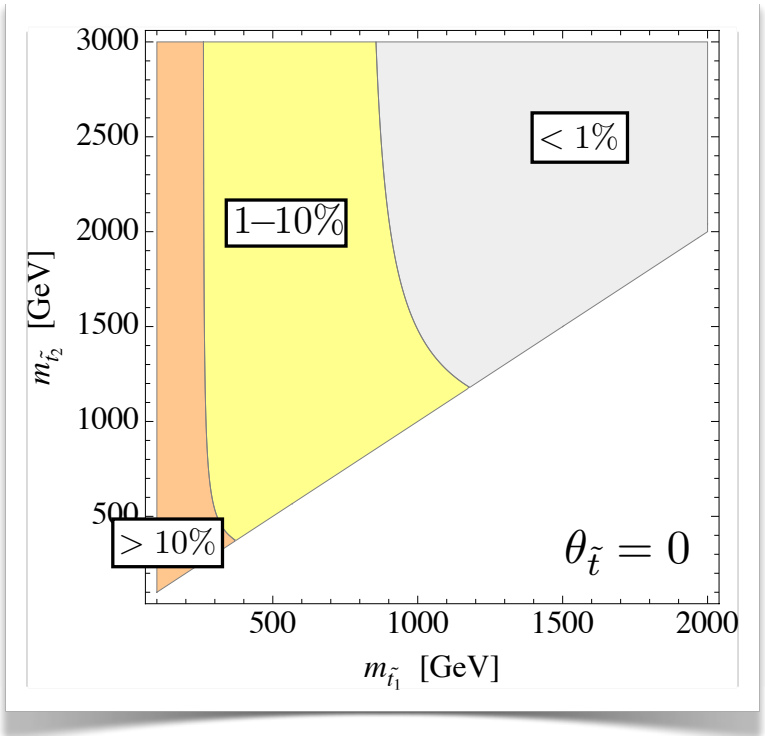
backup slides

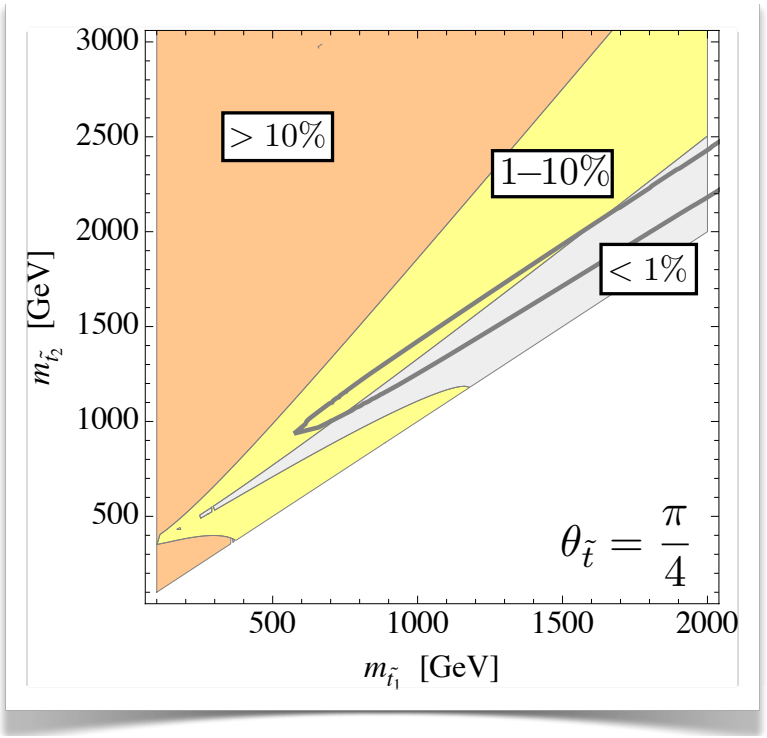
How well we need to measure the Higgs couplings

- Loop-induced couplings (talk by Brian Batell)

Stop

$$\Delta_g^{\tilde{t}} \simeq \frac{1}{4}\left[m_t^2\left(\frac{1}{m_{\tilde{t}_1}^2}+\frac{1}{m_{\tilde{t}_2}^2}\right)-\frac{1}{4}\left(\frac{m_{\tilde{t}_2}}{m_{\tilde{t}_1}}-\frac{m_{\tilde{t}_1}}{m_{\tilde{t}_2}}\right)^2\sin^2 2\theta_{\tilde{t}}\right]$$

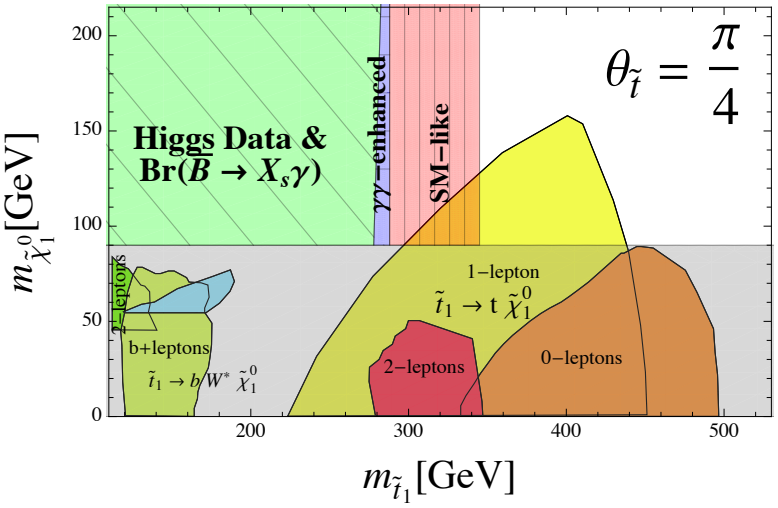




Stop searches and Higgs coupling determination

Veronica Sanz

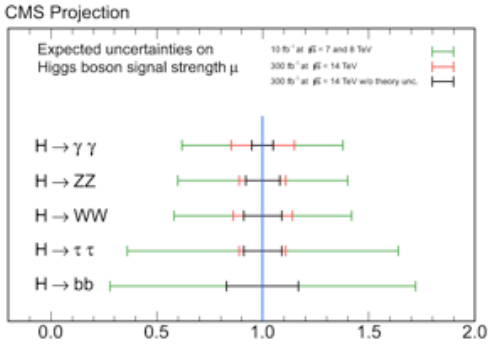
stop exclusion@95%CL using 2012 Higgs data



Note: Higgs-data dominated, quite independent of other observables (b to sgamma, mW), or mixing angle, or final state (MET or no-MET). Valid when tan beta is moderate.

Espinosa, Grojean, VS, Trott, 2012

For snowmass



1. Prospects 300 ifb LHC14
2. Adding staus/sbottoms for large tanbeta
3. Add possible improvements in flavor const
4. ILC/LHC14

How well we need to measure the Higgs couplings

- pMSSM model scan (1-pager from pMSSM group)

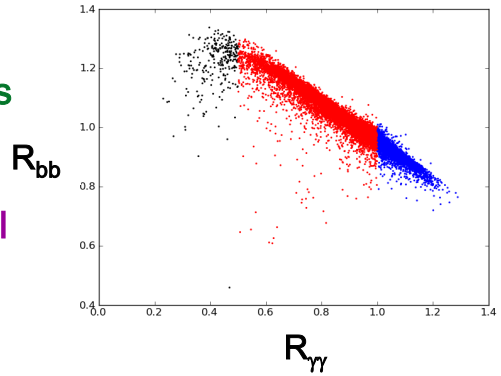
Simultaneous Constraints on Higgs Properties & SUSY Partners in the pMSSM

We will address the questions: "What do direct SUSY searches tell us about the Higgs & what do precision Higgs measurements say about SUSY?" within the context of the pMSSM with either neutralino or gravitino LSPs.

The analysis consists of 2 parts: (i) Determine the 'coverage' of the pMSSM parameter space by the suite of ATLAS (& some CMS) SUSY analyses at 7 & 8 TeV, then extrapolate to 14 TeV. We then use these results to constrain possible deviations in Higgs properties from SM expectations.

(ii) Use the current & extrapolated precision on LHC/ILC Higgs signal strength measurements to extract constraints on sparticle properties.

These analyses will be performed using several existing & one new pMSSM model sets



SLAC NATIONAL ACCELERATOR LABORATORY

M.W. Cahill-Rowley, J.L. Hewett, A. Ismail & T.G. Rizzo

- Simple benchmark models (benchmarks talk by Sally Dawson)

Extended Higgs Sectors

- Many models have more than one Higgs boson
- As a representative set, we will consider:
  - Models with an additional Higgs Singlet
  - Composite Higgs Models
  - 2 Higgs Doublet Models
    - MSSM and NMSSM

Open questions

- CPV Higgs couplings: relation to EDMs? relation to electroweak baryogenesis?

- Higgs and dark matter: what can be learned? (direct detection? colliders?)

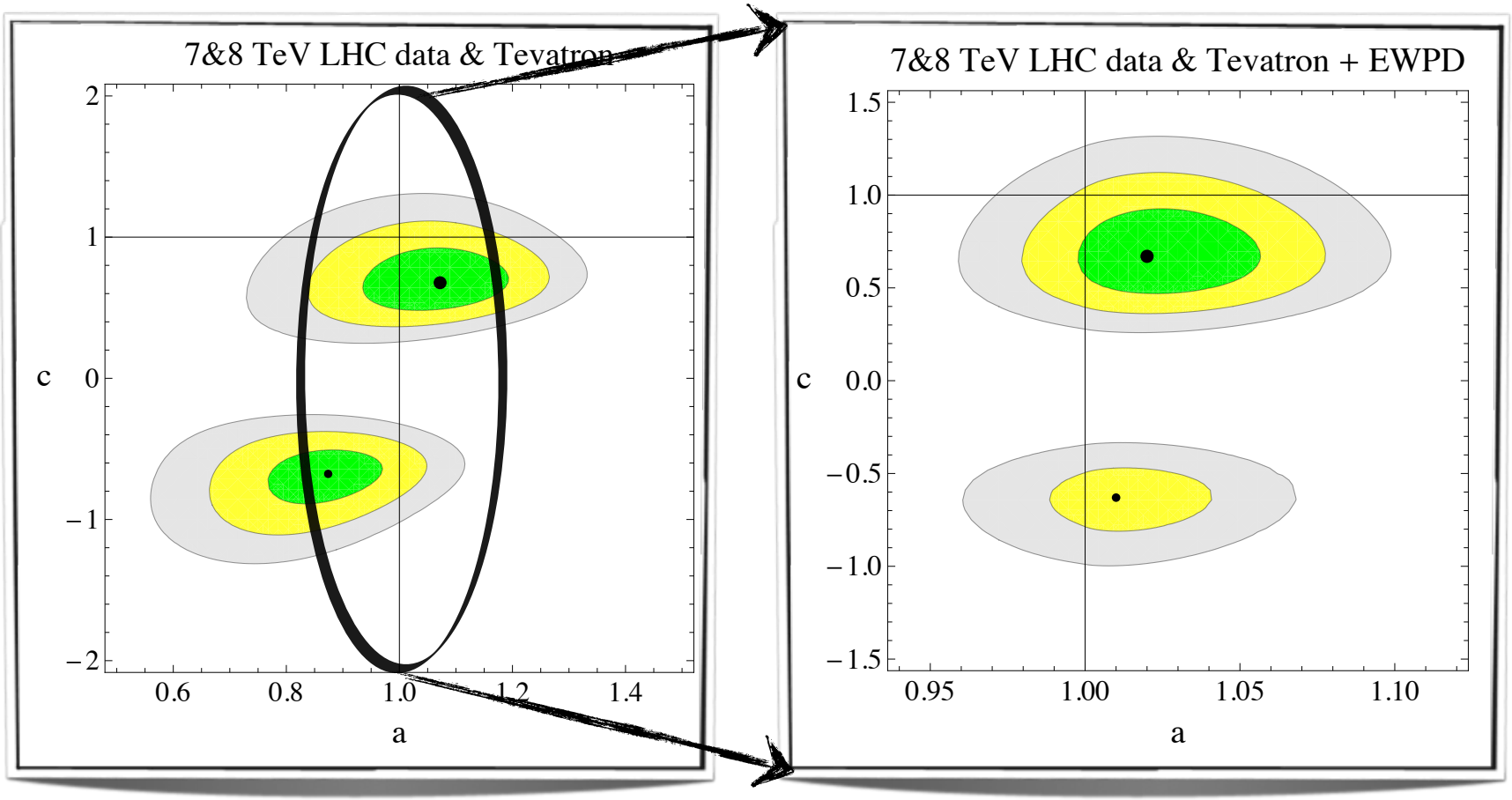
- Higgs couplings vs. electroweak measurements (complementary constraints on dimension-6 operators?)

- What do we learn from the Higgs self-coupling measurement? (BSM benchmarks? EWBG?)

If you have a great idea of something to study for Snowmass, send us a 1-pager proposal and plan to submit a white paper!

RG-Higgs physics: Don't forget LEP!

Espinosa, Grojean, Muhlleitner, Trott '12



EW data prefer value of 'a' close to 1